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Canvas Noise Filtering Techniques in Paintings: A Review

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Abstract: ***An efficient methodology to remove canvas periodic noise from digital images is proposed. The goal is to analyze all methods to detect and analyze periodic noise from digital image of a canvas painting. Various methods are used for the filtering process of noise components like linear filtering and non-linear filtering. All analysis is done on frequency domain for simplicity, by transforming it from spatial domain to frequency transform. By knowing the frequency components and then detecting the abrupt changes in amplitudes in those components gives the noise, which is further moved to the filter treatment process.***
Keywords: ***Digital image of painting; Colour image; Periodic noise; Fourier transform; Filtering; linear filtering; non-linear filtering.***

I. INTRODUCTION

Advancement in image acquisition of paintings or natural images for future records and analysis, led the image specialists to start digitizing the images not only for archiving purpose but also for inspecting the way of art and style of paintings and its authentication [1,2]. The image acquisition further have its own problems of introduction of different noises like Gaussian noise, shot noise etc. but in image digitization of paintings further have problems of physical canvas noise which is periodic in nature. The question was first raised in year 1891 for the painting *Portrait of Suzanne Bambridge* by Paul Gauguin[3]. In the painting, the grid like structure caused by the threads of the canvas sheet was quite disturbing
Where $x(t)$ is input image, $h(t)$ is filter impulse function and $y(t)$ is the output image. The above equation shows the linear convolution [4] or linear filtering technique in noise removal process. It is the earliest technique use for noise removal. This technique only reshape the power spectrum of the original signal but also includes maximum part of noise.
Most of the techniques developed assume a Gaussian noise model, and thus parameters of a system are calculated accordingly. Old image filtering techniques basically based on transform domain filtering and contrast enhancement, and most of them are linear.
Although, in the image processing, it has been proved that the linear techniques are not effective as they are not able to deal with the non-linearities, of the image formation model and don't come in notice of human visual systems. These techniques hence, frequently create blurred images and are not sensitive to impulse noise. Image signals have the composition of unexpected changing areas like intensity, which convey essential information for visual perception. Therefore, in the course of the last 15 years, non-linear methods have been observed to be more impressive for this task. Non-linear methods can suppress non-Gaussian and signal dependent noise in order to preserve crucial signal elements, for example, edges and fine details and discard degradations happening at the time of signal formation or transmission through nonlinear channels.

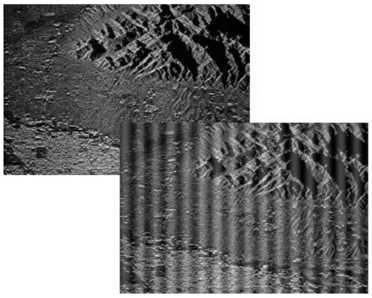

Figure 1: Periodic noise [10].

Transforming of signal from spatial domain to frequency domain gives the frequency components which contains noise as well as information. Periodic (stationary) noise [10] caused by the repetitive behaviour of the threads of paintings is in the form of strips as shown in figure (1).Periodic noise typically arises from interference of light rays during image acquisition [9]. Spatially dependent noise can be effectively removed via frequency domain filtering as noise parameters can be easily determined by estimating the Fourier spectrum of the image, Periodic noise tends to produce frequency components [9] as shown in figure (2).

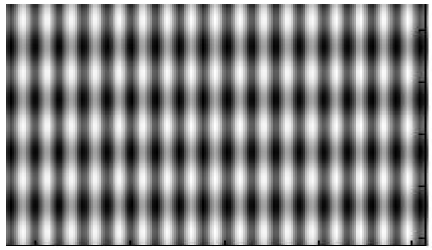

Figure 2: Sample periodic images and their spectra [10].

Periodic noise is a noise which is created by a cyclic process or physically present in the form of threads in case of paintings. In spatial domain periodic noise can be seen as the repetitive patterns after regular interval of dimensions as shown in figure below. Periodic repetition in spatial domain gives the frequency components which are also periodic.

Many applications [3] of digital image processing is required to analyze the noise behavior in order to determine its components and its frequency for further filter treatment process. Noise level estimation is usually done by analyzing the frequency components at which amplitude is changing abruptly. The bulging out of the threads in the painting repeats in a regular pattern is the periodic noise in the painting which must be removed. The periodic behavior of the structure gives the spectra as shown above in the figure. Construction of filter must be in favor of removing maximum content of noise by targeting the band of frequencies at which noise is present without affecting the finer structures of the painting (e.g. brushstrokes, previous restorations or details)..

II. FOURIER TRANSFORM

Fourier transform of any signal helps to know the number of frequency components and their respective amplitudes present in the image signal. The conversion formula from spatial domain to frequency domain is given below.

$$I(u,v)=\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1} i(x,y)e^{-2\pi j(xu/X+yv/Y)}$$

Function '*I*' is the fourier transform of the function in spatial domain function '*i*'. '*u*' and '*v*' are the frequency in two dimension ad '*x*' and '*y*' are the space coordinates of any image signal at the input. *M* and *N* are the total frequency components variation from zero to *N-1*.

Like this if any function whose frequency components are to be known then Fourier transformation is the best method to obtain their respective components. If the components re known then we can easily find out the rapid changes in the components which are referred as the noise or periodic noise in case of paintings.

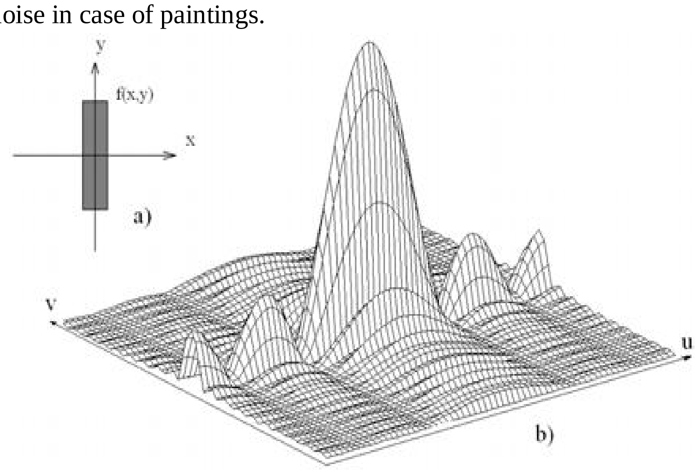

Figure 3: (a) The image in the spatial (b) in the frequency domains. Variable *u* represents horizontal frequency, variable *v* vertical frequency [4].

A. Equations

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III. FILTERING PROCESS

Filters having characteristics of image preservation are very much appropriate for image filtering and improvement. Therefore, the advancement of nonlinear filtering procedures, which works equally fine under wide variety of applications, is of very high importance. Filtering techniques in the frequency domain are based on the Fourier transform and then computing the inverse DFT to get information back to the spatial domain [11]. If '*x*' is an image, then its Fourier transform will give the frequencies of the periodic parts of an image signal '*x*'. By filtering out the unwanted frequencies, one can obtain a new image by applying the inverse Fourier transform.

iltering is a process of retaining desired frequency components containing essential information of an image and removing unwanted components. There are basically four different kinds of filters: low pass, high pass, band pass and band reject filters.

ransform domain techniques are capable of removing some part of the noises. That is why in image enhancement DFT or FFT is used [9-10].

A. Digital filters

In signal processing, a digital filter is a system that performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of that signal. This is in contrast to the other major type of electronic filter, the analog filter, which is an electronic circuit operating on continuous-time analog signals.

A digital filter system usually consists of an analog-to-digital converter to sample the input signal, followed by a microprocessor and some peripheral components such as memory to store data and filter coefficients etc. Finally, a digital-to-analog converter to complete the output stage. Program Instructions (software) running on the microprocessor implement the digital filter by performing the necessary mathematical operations on the numbers received from the ADC.

B. Types of Digital filters

The basic types of digital filters are FIR and IIR filters which are categorized on the basis of their characteristics or impulse response.

1) *FIR (Finite Impulse Response) Filter:* In signal processing, a finite impulse response filter is a filter whose impulse response (or response to any finite length input) is of finite duration, because it settles to zero in finite time. In the common case, the impulse response is finite because there is no feedback in the FIR. A lack of feedback guarantees that the impulse response will be finite. Therefore, the term "finite impulse response" is nearly synonymous with "no feedback".
2) *IIR (Infinite Impulse Response) Filter.:* The impulse response is "infinite" because there is feedback in the filter; if you put in an impulse (a single "1" sample followed by many "0" samples), an infinite number of non-zero values will come out (theoretically). The feedback in the system gives rise to the continuous operation upto no time limit so it is called infinite response filter.

IV. FILTERING TECHNIQUES

A. Linear Filtering

Linear filtering means the filtering technique on linear systems. Linear systems are those systems which follow basic two rules of homogeneity and superposition. Earlier methods of filtering are done by linear filtering but furthermore, advancement in image acquisition and restoration process linear filtering is no longer advantageous. These methods are often used for color improvement also by using equalization techniques.

B. Non-Linear Filtering

Non-linear filtering is the process of filtering on non-linear systems which does not follow linearity as given by above two rules. In image processing since image contains color which has definite frequency due to which, it gives rise to the non-linearity, because of the uneven distribution of frequency components. Some more studies revealed that non-linear filtering is always a factor of improvisation in image processing.

C. Types of Non-Linear Filters

1) *Mean filters:* Mean filters works on the principle of averaging the pixel values of a particular selected kernel. It is a forwarding filter which replaces each and every pixel by its kernel's mean value. It is a non-linear filter which works on the frequencies of different intensities of color in that pixel.
2) *Median Filters:* Median filters working depends on the median of the pixel values in that kernel. It is also a forward moving filter which tests each and every pixel for their values and then assigning the median values to that pixel.

3) *Weiner Filter:* Weiner filtering technique is an optimal technique in removing periodic noise from image. It works on the minimum square error method. It is the approximate analysis of the original image that is, a model is made which approximates the original image by minimizing the square error.

V. LITERATURE SURVEY

A. Ashraf Abdel-Karim Helal Abu-Ein [2014] [9]

In an efficient methodology to remove periodic noise from digital images is proposed. The methodology steps is discussed, analyzed and implemented. Color image is to be converted to gray image, and then 2D fast Fourier transform (2DFFT) is to be applied on the gray image. The magnitude of applying 2DFFT is to be analyzed in order to get the periodic filter, which is to be correlated with the magnitude matrix, and the output of correlation is to be used with the angle matrix to get the de-noised gray image.

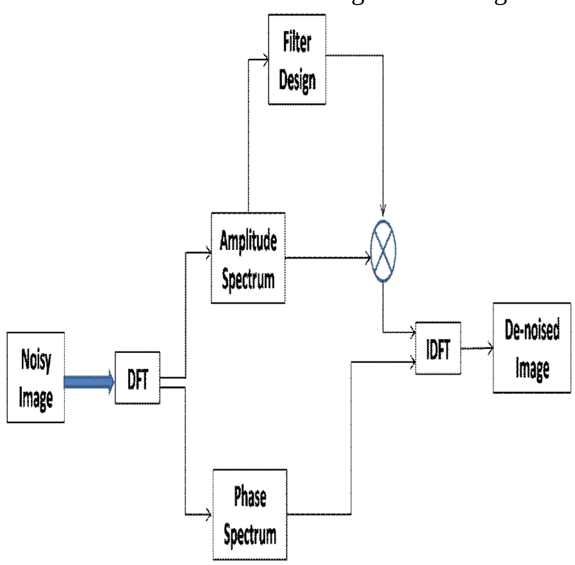

Figure 4: Methodology for periodic noise removal process
Methodology for periodic noise removal

The proposed methodology consists of the following sequence of steps:
Step1: Acquire the color image, apply direct conversion to convert color image to gray image and save the red and green components to be used later on in indirect conversion.
Step2: Transfer the gray image representation from time domain to frequency domain by applying 2D FFT which gives us the magnitude and angle matrix of the image, save the angle matrix to be used later on.
Step3: Analyze the magnitude matrix spectrum and prepare the filter mask.
Step 4: Correlate the magnitude matrix with filter mask.
Step 5: Use the correlated matrix and angle matrix and apply inverse FFT to get the new gray image.
Step 6: Apply inverse conversion to get the cleared color image.

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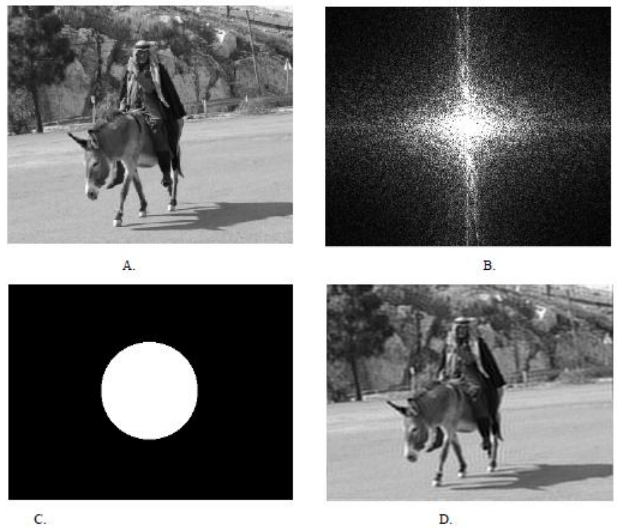


Figure 5: (a) Input image, (b) the spectrum of input image, (c) the ideal low pass filter, (d) result of filtration in spatial domain

In the above method ringing effect can be seen in the final image.

B. Mandeep Kaur et.al., [2015] [10]

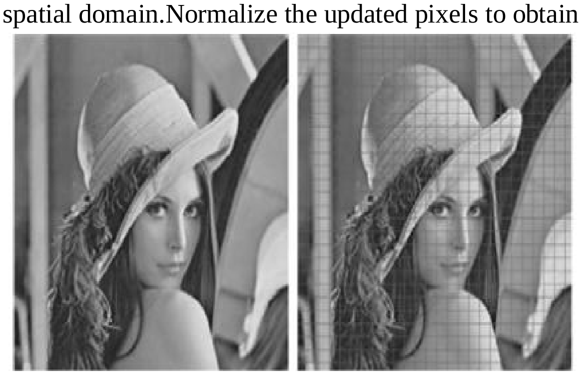
In this paper [3] a 2-D FFT removal algorithm for reducing the periodic noise in natural and strain images is proposed. For the periodic pattern of the artifacts, we apply the 2-D FFT on the strain and natural images to extract and remove the peaks which are corresponding to periodic noise in the frequency domain. Further the mean filter applied to get more effective results. The performance of the proposed method is tested on both natural and strain images. In this work two set of algorithms are presented.

C. Algorithms 1: Peak Detection in the Frequency Domain

1) Define a detection route such that the detected peaks are stored in an ascending order in terms of the distance to the origin (where the origin is the centre of the spectrum domain). Note that if only processes in the right half space of the centre because of the symmetry of the peaks (impulses) in the spectrum domain.
2) Define a local window of the size X*Y (where X and Y are odd) and find the maximum from the window pixels.
3) If the current pixel is just the same as the local maximum and also it is above a given threshold, it will be a new detected peak.

D. Algorithm2: Noise Removal Algorithm

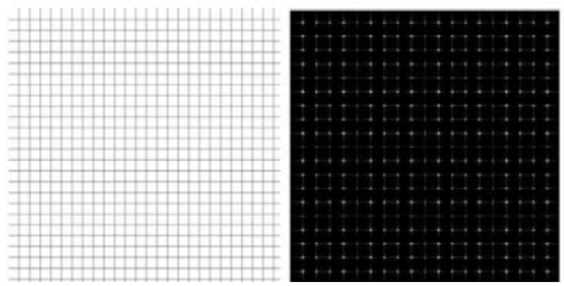
1) Take a 2-D FFT to the processing image
2) Use Algorithm 1 for local peaks detection in the frequency domain
3) Compute the direction groups and define the set of deleted impulses
4) Remove the selected impulses by using Algorithm 1, and then take the inverse 2-D FFT
5) Apply the mean filter to suppress the peaks
6) Apply the inverse 2D FFT for the spatial domain.Normalize the updated pixels to obtain the same mean as the old.



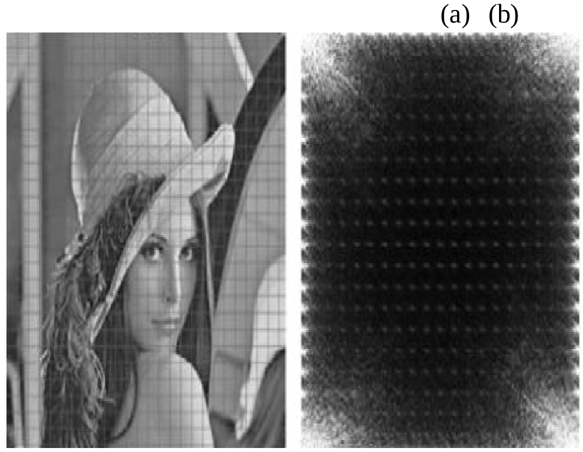
(a) (b)

(c) (d)

Figure 6: (a) Original image (b) noisy image (c) filtered by mean filter (d) filtered by proposed method



(a) (b)



(c) (d)

Figure 7: (a) white image is corrupted with periodic noise, (b) frequency domain image, (c) Lena image corrupted with periodic noise, (d) frequency domain image

E. Fedric Sur [2015]

Images can be affected by quasi-periodic noise [9]. This undesirable feature manifests itself by spurious repetitive patterns covering the whole image, well localized in the Fourier domain.

While notch filtering permits to get rid of this phenomenon, this however requires to first detect the resulting Fourier spikes, and, in particular, to discriminate between noise spikes and spectrum patterns caused by spatially localized textures or repetitive structures. This work proposes a statistical a-contrario detection of noise spikes in the Fourier domain.

VI. CONCLUSIONS

Filters are essential components in image processing. Using filters, noise cannot be completely eliminated but they suppress noise and produce a good quality image by removing noises. Above all methods uses techniques which reduces noise and improves the image but have problems in blurring of image edges in case of linear and mean filtering but Weiner filtering is optimal for that case but Weiner filtering process further assumes the noise factor for the estimation of approximate image model. So all above studies and discussions on filtering and detection of noise produces a further discussion on the future model, which must be adaptive to the spectrum of natural images so that any of the image can be analyzed mathematically and further detects the noise adaptively**.**

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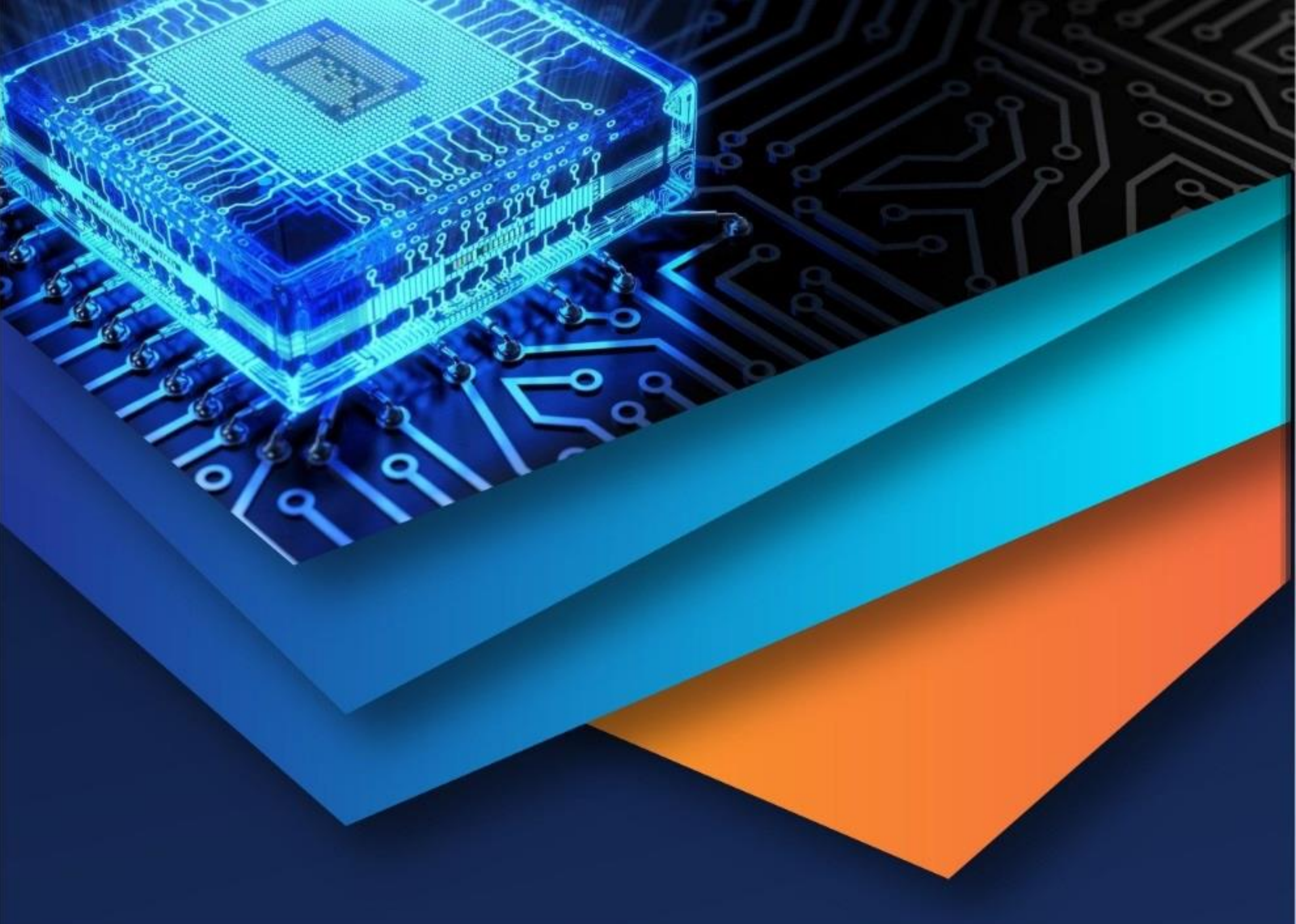

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